
MYCOTAXON

ISSN (print) 0093-4666 (online) 2154-8889 Mycotaxon, Ltd. ©2018

January–March 2018—Volume 133, pp. 103–112

<https://doi.org/10.5248/133.103>

New records of *Arthoniaceae* from Vietnam

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ABSTRACT—*Arthonia complanata*, *A. elegans*, *A. pyrrhuliza*, *Arthothelium ruanum*, *A. spectabile*, and *Herpothallon minimum* are newly reported from Vietnam. An identification key is provided to the 18 *Arthoniaceae* species known from Vietnam.

KEY WORDS—corticolous, lichenized fungi, mangrove, national park, taxonomy

Introduction

The present study was conducted at low (<300 m) elevations of southern Vietnam in two national parks: Nam Cat Tien National Park and Dan Xay Mangrove Park. In addition to several interesting elements in *Graphidaceae*, *Pyrenulaceae*, and *Trypetheliaceae*, the national parks revealed the significant occurrence of arthonioid lichens. The *Arthoniaceae* have been little studied in Vietnam: Aptroot & Sparrius (2006) catalogued seven species, *Arthonia antillarum* (Fée) Nyl., *A. cinnabarina* (DC.) Wallr., *A. cyanea* Müll. Arg., *A. microcephala* Vězda, *Crypthonia mycelioides* (Vain.) Frisch & G. Thor, *Herpothallon rubrocinctum* (Ehrenb.) Aptroot & al., and *Myriostigma candidum* Kremp., together with some doubtful species records. Nguyen & al. (2011) recorded *Arthonia accolens* Stirt., while Joshi & al. (2014, 2015) added *Arthonia diorygmatis* S. Joshi & Upreti, *A. excipienda* (Nyl.) Leight., *A. radiata* (Pers.) Ach., and *Herpothallon sipmanii* Aptroot & al.

Our study presents six new Vietnamese records of corticolous lichenized fungi representing *Arthonia*, *Arthothelium*, and *Herpothallon*. An identification key to the *Arthoniaceae* species known from Vietnam is included.

Materials & methods

Lichen specimens collected in December 2015 were deposited in Korea National Arboretum (KH), Pocheon, South Korea in 2016, and samples were studied in the Lichenology laboratory of CSIR-National Botanical Research Institute, Lucknow, India. The morphology was examined using a MSZ-TR dissecting microscope and a Leica DM 500 compound microscope. The following literature was consulted for the identifications: Willey 1890; Awasthi 1991; Makhija & Patwardhan 1995; Aptroot & Sparrius 2006; Grube 2007; Aptroot & al. 2009; Smith & al. 2009; Bungartz & al. 2013; Frisch & Thor 2010; Nguyen & al. 2011; Joshi & al. 2013, 2014, 2015; Jagadeesh Ram & Sinha 2016; Lee & Hur 2016. Thin layer chromatography (TLC) in solvent system A was performed following Orange & al. (2010). Lugol's solution was used to check amyloidity (I+ or I-). Illustrations were prepared using Corel Draw (ver. 12).

Taxonomy

Arthonia complanata Fée, Essai Crypt. Exot.: 54, 1825 ["1824"]. PL. 1A

Thallus epiperidermal, pale green to off-white, evanescent, delimited by brownish black prothallus, 50–80 µm thick; photobiont trentepohlioid; medulla partly immersed, white; ascomata immersed to emergent, round, shortly linear, flat to convex, black, epruinose, 0.5–1 × 0.3–0.6 mm; epihymenium brownish, K+ greenish, 10–15 µm high; hymenium hyaline to yellowish, filled with a gel matrix, 80–90 µm high, I+ blue; hypothecium hyaline to yellowish, 20–25 µm; asci 8-spored, 70–80 × 25–30 µm, I+ wine red; ascospores soleiform, hyaline, soon becoming brown, transversely 3–4-septate, with large, undivided upper and lower cells, 20–28 × 7–11 µm, I-.

CHEMISTRY—No chemicals detected with TLC.

DISTRIBUTION & ECOLOGY—This species has a tropical distribution (Willey 1890). In Vietnam, *A. complanata* was growing in small and irregular patches on thick and smooth barked trees in association with *Arthothelium* spp.

SPECIMEN EXAMINED: VIETNAM. DONG NAI PROVINCE: Tan Phu district, Nam Cat Tien National Park, 11°24'20"N 107°17'19"E, alt. 256 m, on bark, 17 December 2015, Hur & Woo VN150021 (KH).

REMARKS—Enlarged cells at both the ends of ascospores are characteristic of *Arthonia complanata* and distinguish it from *Arthonia excedens* Nyl., which also differs in producing larger ascospores (30–36 × 10–15 µm; Willey 1890, Lee & Hur 2016). Initially, the Vietnamese sample was wrongly interpreted

as *Arthonia ilicinella* Nyl. based on the smaller ascospore size ($18\text{--}23 \times 7\text{--}9\ \mu\text{m}$) cited in the Smith & al. (2009) description. Subsequent comparison of our sample with the description of *A. ilicinella* provided by Nylander (1867) indicated that the *A. ilicinella* ascospores were larger ($21\text{--}36 \times 8\text{--}12\ \mu\text{m}$).

Arthonia elegans (Ach.) Almq.,

Kongl. Svenska Vetensk. Acad. Handl., n.s., 17(6): 19, 1880.

PL. 1B

Thallus mostly endoperidermal reflecting bark texture, whitish to pale green delimited by dark brown prothallus, $50\text{--}80\ \mu\text{m}$ thick; photobiont trentepohlioid; medulla endoperidermal; ascomata linear, irregularly to stellately branched, reddish black, epruinose to reddish brown pruinose near the margins, $1\text{--}2 \times 0.1\text{--}0.2\ \text{mm}$; epihymenium reddish brown, K+ purple-red, $5\text{--}10\ \mu\text{m}$ high; hymenium hyaline or pale yellow-reddish with anastomosed paraphysoids in a gel matrix, $25\text{--}50\ \mu\text{m}$ high, I+ bluish; hypothecium pale yellow-reddish to brownish, $20\text{--}25\ \mu\text{m}$ high; ascus 8-spored, $20\text{--}25 \times 10\text{--}15\ \mu\text{m}$, I+ bluish; ascospores hyaline, soleiform, transversely 4–5-septate with upper enlarged cell, $10\text{--}12 \times 3\text{--}5\ \mu\text{m}$, I–.

CHEMISTRY—No lichen substances detected with TLC.

DISTRIBUTION & ECOLOGY—Previously known from temperate Europe (Acharius 1810). In Vietnam, it was collected from smooth barked trees.

SPECIMEN EXAMINED: VIETNAM. DONG NAI PROVINCE: Tan Phu district, Nam Cat Tien National Park, $11^{\circ}26'40''\text{N}$ $107^{\circ}24'23''\text{E}$, alt. 164 m, on bark, 18 December 2015, Hur & Woo VN150264 (KH).

REMARKS—*Arthonia elegans*, which is in need of urgent taxonomic revision, has been treated under different concepts by various authors. Acharius (1810) did not provide spore sizes in his type description of *Spiloma elegans*. Almquist (1880) reported $15\text{--}18 \times 7\text{--}8\ \mu\text{m}$ spores (3-septate only), $45 \times 22\ \mu\text{m}$ asci, and ochre pruinose ascomata, while Smith & al. (2009) described a different taxon (*A. elegans* sensu auct. brit., non (Ach.) Almq.), citing $14\text{--}19 \times 4.5\text{--}7\ \mu\text{m}$ spores (2–5-septate). Although our Vietnamese specimen has even smaller asci and ascospores, it may be either referred to a very broad concept of *Arthonia elegans* s.l. (with a wide range of ascospore sizes, $10\text{--}19 \times 3\text{--}8\ \mu\text{m}$) or represent an unnamed new species.

Arthonia pyrrhuliza Nyl., Flora 68: 447, 1885.

PL. 1C

Thallus epiperidermal, whitish grey to off-white, $\pm$ rimose, delimited by brownish prothallus, $70\text{--}150\ \mu\text{m}$ thick; photobiont trentepohlioid; medulla epiperidermal, white, crystalline; ascomata shortly lirellate, linear to bi- or trifurcate, cracked near margins, reddish brown to brown, $0.5\text{--}1 \times 0.02\text{--}0.05$

mm, the decaying or infected discs appear dark brown to black; epihymenium brownish, K+ greenish, 15–20 μm high; hymenium hyaline to yellowish, clear, with anastomosed paraphysoids in a gel matrix, 70–80 μm high, I+ blue; hypothecium indistinct; asci broadly clavate, 8-spored, 60–75 $\times$ 30–32 μm , I+ wine red; ascospores hyaline, soleiform, with undivided upper cell, tapering at one end, transversely 4-septate, 30–35 $\times$ 10–12 μm , I–.

CHEMISTRY—No chemicals detected with TLC.

DISTRIBUTION & ECOLOGY—This maritime species was previously recorded from North America (Grube 2007). In Vietnam, *A. pyrrhuliza* was collected from mangrove forests on thin and $\pm$ rough barked trees, where it was growing together with *A. antillarum*.

SPECIMENS EXAMINED: VIETNAM. HO CHI MINH CITY: Can Gio district, Dan Xay Mangrove Park, alt. 13 m, 10°27'35"N 106°54'16"E, on bark, 21 February 2015, Hur & Woo VN150416, VN150417, VN150418, VN150419B, VN150420, VN150426, VN150427, VN150429, VN150436, VN150439 (KH).

REMARKS—Superficially, the species can wrongly be interpreted as *Enterographa* spp., which however has entirely different apothecial anatomy. *Arthonia pyrrhuliza* ascospores have been recorded as 12–15 $\times$ 4.5 μm (Willey 1890) and 13–19 $\times$ 5–7 μm (Grube 2007); however, Vietnamese material differs in producing significantly larger ascospores, appearing much closer in morphology and ascospore size (25–43 $\times$ 10–15 μm) to *Arthonia rubella* (Fée) Nyl., which is otherwise distinguished by its ascospores with undivided and rarely tapered large cells at both ends (Willey 1890; Brodo & al. 2001). Given the contradiction with previous descriptions, it is also possible that our material represents an undescribed species. At this time we choose to refer our Vietnamese specimens to *A. pyrrhuliza*, noting that most parts were infected with some lichenicolous fungus producing a black powdery mass.

Arthothelium ruanum (A. Massal.) Körb., Parerga Lichenol. 3: 263, 1861. PL. 1D

Thallus endoperidermal, thin, brownish grey to off-white, delimited by dark brown to blackish prothallus, ≤ 50 μm thick; photobiont trentepohlioid, layer poorly developed, mostly dispersed; medulla indistinct to endoperidermal; ascomata scattered to aggregated, numerous, immersed, irregular to bluntly stellate, brownish black, epruinose, sometimes covered marginally with thalline layer, 0.5–1 mm in diam.; epihymenium dark brown, K+ greenish, 10–15 μm high; hymenium hyaline to brownish, clear, with adglutinate paraphysoids, 50–60 μm high, I+ bluish; hypothecium brown, 20–25 μm high; asci 8-spored, 30–50 $\times$ 15–20 μm , I+ wine red; ascospores hyaline, muriform (10–15 transverse septa and 2–4 longitudinal septa), 20–25 $\times$ 7–10 μm , I–.

CHEMISTRY—No lichen substances detected in TLC.

DISTRIBUTION & ECOLOGY—*Arthothelium ruanum* occurs in Europe, North America, and Asia (Smith & al. 2009, Joshi & al. 2013). In Vietnam, it was collected from thin- and smooth-barked trees.

SPECIMEN EXAMINED: VIETNAM. DONG NAI PROVINCE: Tan Phu district, Nam Cat Tien National Park, 11°25'19"N 107°25'41"E, alt. 135 m, on bark, 18 December 2015, Hur & Woo VN150290 (KH).

REMARKS—*Arthothelium ruanum* has also been treated under *Arthonia* as *A. ruana* A. Massal., following incessant discussions and arguments regarding the diagnostic importance of spore septation. Generic delimitation between *Arthonia* and *Arthothelium* is for the most part based on ascomal development (stromatic vs. solitary), epithecium (persistent vs. eroding), arrangement (loose vs. dense) of interascal filaments, and synchronous vs. irregular ascal development (Coppins & James 1979, Grube & Giralt 1996, Lee & Hur 2016). Until there are more extensive studies and wide acceptance of this generic delimitation, we cautiously refer our Vietnamese specimen to *Arthothelium*.

Arthothelium spectabile A. Massal., Ric. Auton. Lich. Crost.: 54, 1852. PL. 1E

Thallus endoperidermal, whitish grey to dull grey, delimited by blackish prothallus, 100–170 µm thick, photobiont trentepohlioid, layer distinct, continuous, 60–80 µm thick; medulla endoperidermal; ascomata scattered, immersed, roundish, irregular to shortly elongate, ± flat, black, epruinose, flaking away from the thallus at maturity, 0.5–1 × 0.3–0.5 mm; epihymenium brownish green, K+ greenish, 10–15 µm high; hymenium ± hyaline, interspersed with oil droplets, 80–100 µm high, I+ blue; hypothecium hyaline to yellowish, 20–25 µm high; asci 8-spored, 50–80 × 45–50 µm, I + bluish; ascospores hyaline to brownish in late maturity, muriform (10–15 transverse septa and 2–4 longitudinal septa), 35–40 × 10–15 µm, I–.

CHEMISTRY—No lichen substances detected with TLC.

DISTRIBUTION & ECOLOGY—Cosmopolitan (Makhija & Patwardhan 1995; Smith & al. 2009). In Vietnam, *A. spectabile* was growing luxuriantly in mangrove forests and collected from thick and rough barked trees.

SPECIMENS EXAMINED: VIETNAM. DONG NAI PROVINCE: Tan Phu district, Nam Cat Tien National Park, 11°24'20"N 107°17'19"E, alt. 256 m, on bark, 17 December 2015, Hur & Woo VN150070 (KH); Yak farm, 11°23'10"N 107°21'46"E, alt. 128 m, on bark, 17 December 2015, Hur & Woo VN150149 (KH).

REMARKS—The Vietnamese specimens agree well with previous descriptions of *A. spectabile* and differ from the closely related *A. keralense* Makhija & Patw., which has a thicker algal layer (50–150 µm; Makhija & Patwardhan 1995).

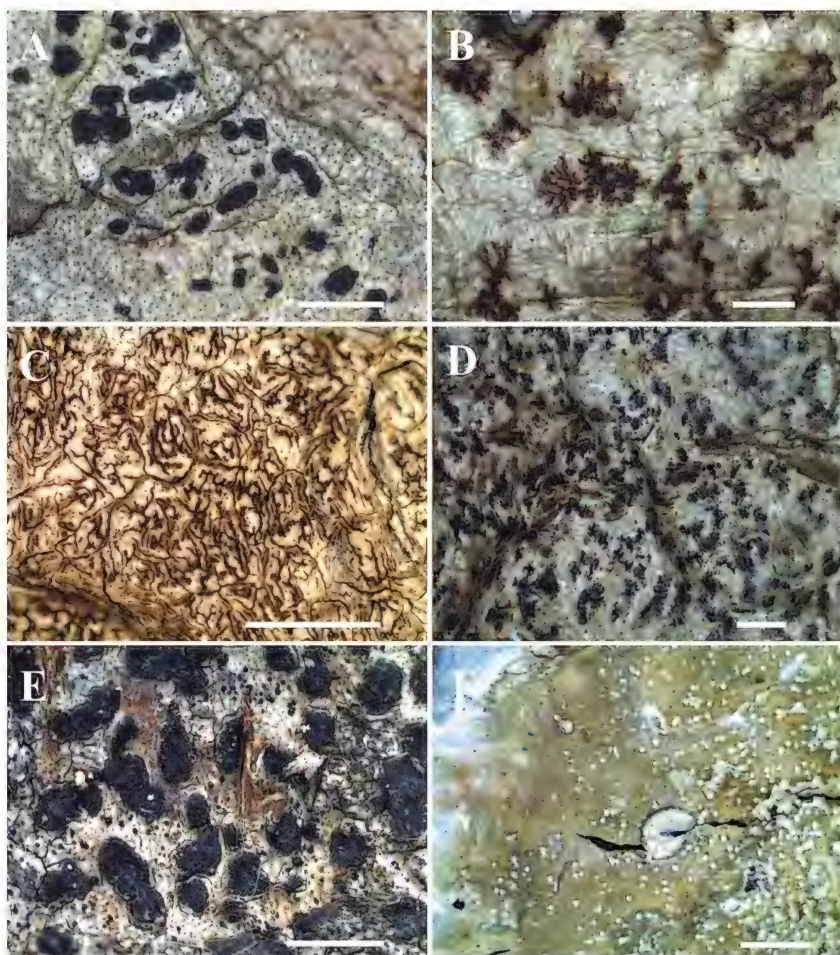


PLATE. 1. Arthoniaceae species newly recorded from Vietnam. A. *Arthonia complanata*; B. *Arthonia elegans*; C. *Arthonia pyrrhuliza*; D. *Arthothelium ruanum*; E. *Arthothelium spectabile*; F. *Herpothallon minimum*. Scale bars = 1 mm.

Herpothallon minimum Aptroot & Lücking, Biblioth. Lichenol. 99: 53, 2009. PL. 1F

Thallus epiperidermal, off-white, pale greenish grey or mineral-grey, ecorticate, sterile, resting on white, byssoid hypothallus, closely adpressed to the substrate, delimited by a broad prothallus of loosely radiating fibrous strands of white hyphae, $\leq 150 \mu\text{m}$ thick; abundantly covered with irregular to cylindrical pseudoisidia, $\leq 0.05 \text{ mm}$ long and wide, loose-byssoid, irregular, whitish hypothallus; pycnidia present at the tip of pseudoisidia as black dots.

CHEMISTRY—2'-O-methylperlatolic acid detected with TLC.

DISTRIBUTION & ECOLOGY—Recorded from America and Africa (Aptroot & al. 2009). In Vietnam, *H. minimum* was luxuriantly colonized under shaded trees of seasonal forests in the low-land humid climate of the national park.

SPECIMENS EXAMINED: VIETNAM. DONG NAI PROVINCE: Tan Phu district, Nam Cat Tien National Park, 11°26'43"N 107°24'21"E, alt. 166 m, on bark, 18 December 2015, Hur & Woo VN150269 (KH); 11°26'32"N 107°24'55"E, alt. 151 m, on bark, 19 December 2015, Hur & Woo VN150346, VN150349 (KH); 11°26'60"N 107°21'48"E, alt. 163 m, on bark, 19 December 2015, Hur & Woo VN150395 (KH).

REMARKS—The Vietnamese specimens agree well with the type description of *Herpothallon minimum* (Aptroot & al. 2009), but the Vietnamese specimens were initially incorrectly accommodated under *H. granulare* (Sipman) Aptroot & Lücking as a result of their pseudoisidia being misinterpreted as soredia-like granules.

Key to species in Arthoniaceae recorded from Vietnam

1. Thallus absent, lichenicolous on *Diorygma*; ascomata dot-like, round, irregular to shortly lirellate, prominent; epihymenium K+ purple, hymenium interspersed (with oil droplets); ascospores hyaline becoming dark brown and warty, 1-septate, $10\text{--}16 \times 4\text{--}5\ \mu\text{m}$ *Arthonia diorygmatis*
1. Thallus present, non-lichenicolous 2
2. Thallus fertile, byssoid or crustose, ascigerous area organized or not 3
2. Thallus sterile, byssoid, leprose, pseudoisidia present, hypothallus distinct; prothallus made up of radiating hyphae 15
3. Thallus foliicolous or corticolous, byssoid, ecorticate, ascigerous area unorganized, asci closely aggregated in distinctly raised, maculate, flat, $\pm$ rounded structures; ascospores muriform, $45\text{--}65 \times 15\text{--}25\ \mu\text{m}$; 2'-O-methylantraic and 2'-O-methylperlatolic acids present; hymenium clear or interspersed *Myriostigma candidum*
3. Thallus crustose; ascigerous area well organized 4
4. Ascospores transversely septate 5
4. Ascospores muriform 14
5. Thallus foliicolous 6
5. Thallus corticolous 8
6. Ascomata black, very small (0.1–0.2 mm diam.), epruinose; ascospores microcephalic, often with one median cell slightly larger, 3-septate ($14\text{--}16 \times 4\text{--}5\ \mu\text{m}$) *Arthonia microcephala*
6. Ascomata variously coloured, medium-sized to large (0.3–1.0 mm diam.); ascospores macrocephalic, with the distal cell distinctly enlarged, 2–3(–5)-septate 7

7. Ascomata light to dark brown, epruinose, sharply delimited;
ascospores hyaline, 2-septate, $10-16 \times 4-5 \mu\text{m}$ *Arthonia accolens*
7. Ascomata greenish brown to bluish grey, with a white pruina giving
a bluish appearance; ascospores hyaline to rarely slightly greyish brown,
regularly 2–5-septate, $(6-)9-25 \times 2-8 \mu\text{m}$ *Arthonia cyanea*
8. Ascomata pigmented, $\pm$ pruinose, epihymenium K+ purple 9
8. Ascomata unpigmented, epruinose, epihymenium K+ greenish or K- 10
9. Ascomata mostly round to irregular, brown, white pruinose;
margins with cinnabar-red pruina, $0.5-1 \times 0.2-0.8 \text{ mm}$;
ascospores hyaline to brown at maturity, transversely 3–5-septate,
 $15-20 \times 7-9 \mu\text{m}$ *Arthonia cinnabarina*
9. Ascomata shortly elongate, irregularly to stellately branched, black, epruinose
to reddish brown pruinose near the margins, $1-2 \times 0.1-0.2 \text{ mm}$;
ascospores hyaline, transversely 5-septate, $10-12 \times 3-5 \mu\text{m}$... *Arthonia elegans*
10. Ascomata pale brown to reddish brown 11
10. Ascomata black 12
11. Ascomata pale brown, round to irregular, $1-2 \times 0.5-1 \text{ mm}$;
ascospores hyaline transversely 1–3-septate,
 $11-17 \times 4-7 \mu\text{m}$ *Arthonia antillarum*
11. Ascomata reddish brown, shortly elongate, linear, bi- or trifurcate;
ascospores hyaline, transversely 4-septate,
 $30-35 \times 10-12 \mu\text{m}$ *Arthonia pyrrhuliza*
12. Ascomata round to irregular; ascospores hyaline to grey-brown at maturity,
transversely 3–4-septate, with large, undivided upper and lower cells,
 $20-28 \times 7-11 \mu\text{m}$ *Arthonia complanata*
12. Ascomata substellate or slightly elongate 13
13. Ascomata substellate to irregular, 1–1.5 mm in diam.;
ascospores hyaline to grey brown, transversely 3-septate,
 $14-16 \times 4-5 \mu\text{m}$ *Arthonia radiata*
13. Ascomata slightly elongate, often curved or flexuose, occasionally
branched with a slightly raised margin, $1-1.5 \times 0.1-0.5 \text{ mm}$;
ascospores hyaline, 1-septate, $20-25 \times 8-10 \mu\text{m}$ *Arthonia excipienda*
14. Thallus thin, algal layer indistinct; ascomata reddish black, 1–2 mm in diam.;
ascospores hyaline, $20-25 \times 7-10 \mu\text{m}$ *Arthothelium ruanum*
14. Thallus thick, algal layer $\pm$ distinct; ascomata black,
flaking away from the thallus at maturity, $0.5-1 \times 0.3-0.5 \text{ mm}$;
ascospores hyaline, soon brownish, $35-40 \times 10-15 \mu\text{m}$ *Arthothelium spectabile*
15. Thallus pale mineral-grey to green or whitish green,
hypothallus brown; prothallus made up of radiating whitish hyphae;
pseudoisidia disc-shaped (schizidia), pale to off-white,
flattened to slightly convex with round to wavy margin, $\leq 1 \text{ mm diam.}$;
protocetraric and hypoprotocetraric acids present *Herpothallon sipmanii*

15. Thallus colour various; pseudoisidia loose or compact, cylindrical to irregular;
chemistry lacking protocetraric and hypoprotocetraric acids 16
16. Pigments absent; 2'-O-methylperlatolic acid present *Herpothallon minimum*
16. Pigments (K+ purple) present; lacking 2'-O-methylperlatolic acid 17
17. Thallus greenish grey to greyish orange, rather loose; hypothallus byssoid,
brownish to greenish black; prothallus whitish to pale greenish orange;
pseudoisidia cylindrical rarely globose, byssoid, concolorous with thallus
or strongly pigmented, ≤0.6 mm long and wide;
norstictic acid present *Cryptothonia mycelioides*
17. Thallus greenish grey to reddish green; hypothallus and prothallus byssoid,
deep red; pseudoisidia rather compact and robust, entirely red, 0.5 × 0.4 mm;
chiodectonic acid present *Herpothallon rubrocinctum*

Acknowledgments

This work was supported by a grant from the Korea National Research Foundation (NRF-2015K2A1B7A01069080, NRF-2014M3A9B8002115). Santosh Joshi expresses sincere gratitude to the Director, CSIR-NBRI, Lucknow, India for providing laboratory facilities. The authors are grateful to Dr László Lőkös (Department of Botany, Hungarian Natural History Museum, H-1437 Budapest, Pf. 137, Hungary) and Dr Sergey Y. Kondratyuk (M.H. Kholodny Institute of Botany, Kiev, Ukraine) for their valuable comments on the manuscript.

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